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THE FILLING FACILITY FOR LMJ CRYO TARGETS

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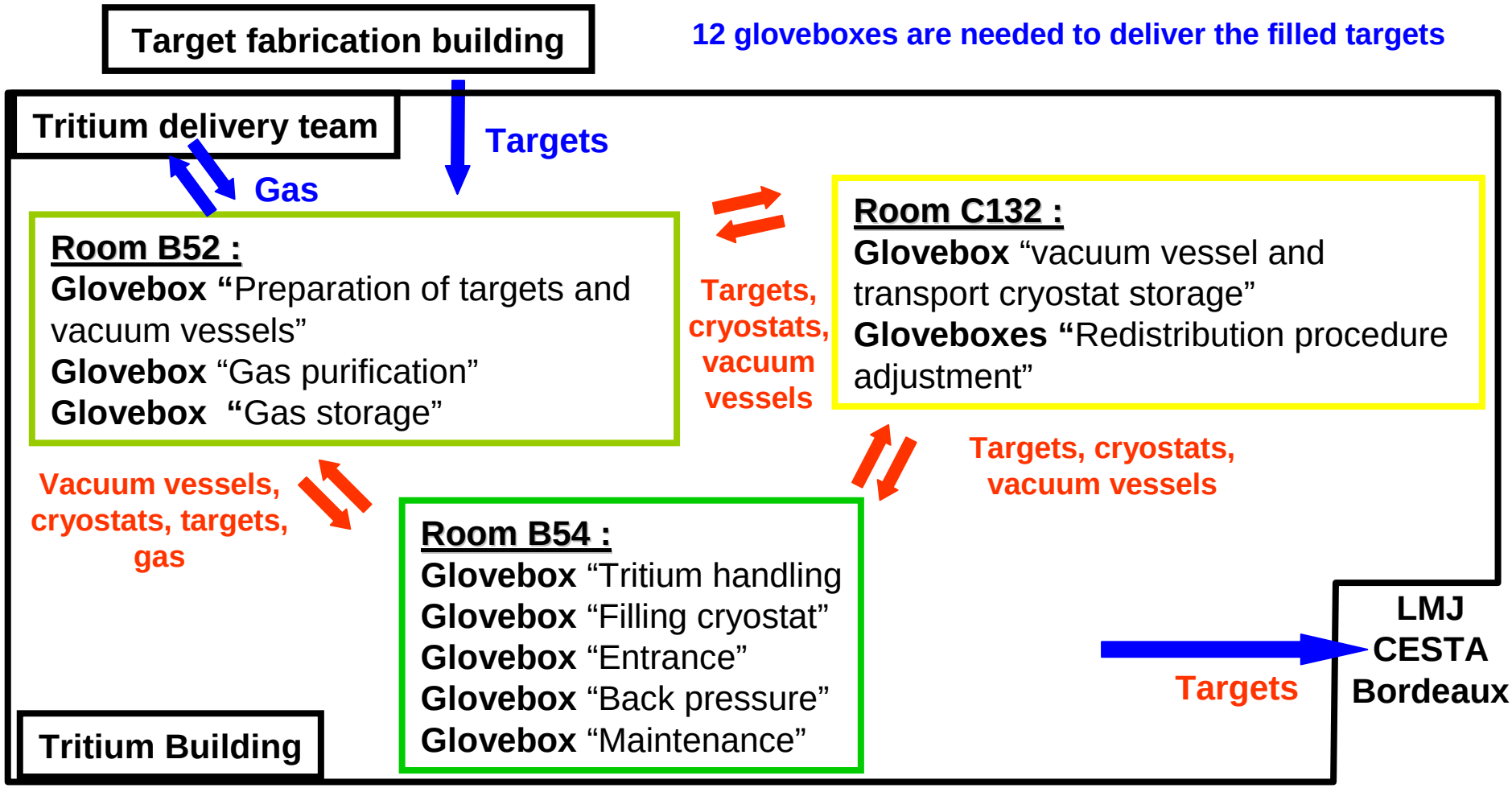
- **Whole gloveboxes chain**

For the French Inertial Confinement Fusion (ICF) experiments carried out on the Megajoule Laser (LMJ), cryogenic target are manufactured and filled thanks to CEA Valduc tritium facilities.

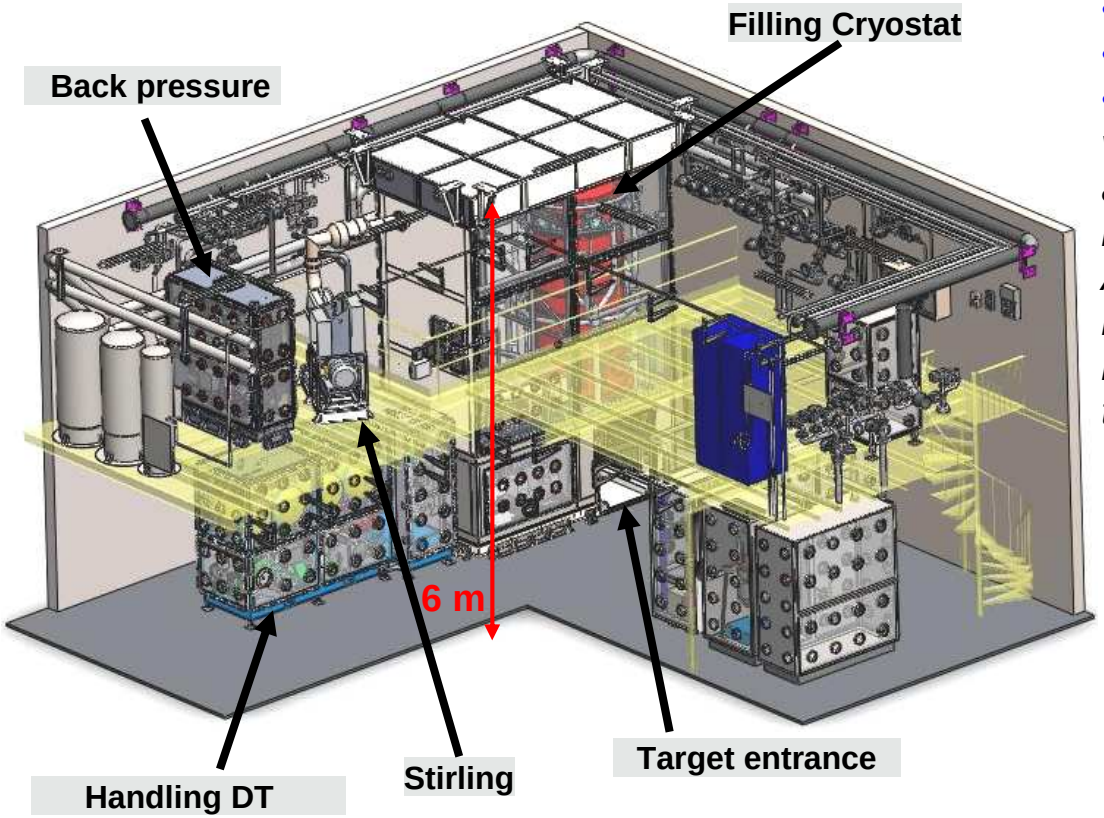


- **Room B54 : Cryogenic target filling and cooling station**

The permeation filling process is one of the possibilities to fill an LMJ target for ignition.

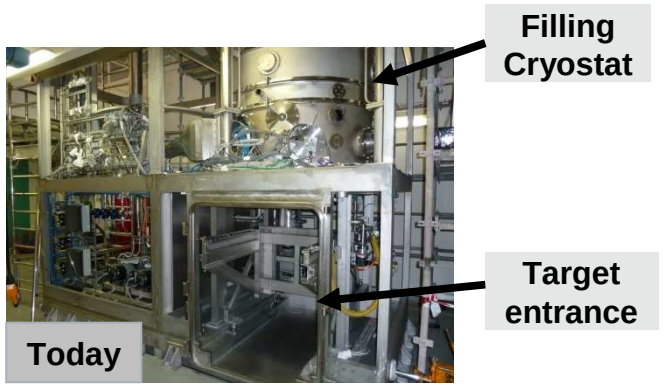
A Target is filled with DT at 300 K up to 1300 bars (maximum pressure to cover all the needs of target designers) in a permeation cell. The permeation cell is then cooled down to 20 K to lower the residual vapour pressure in the capsule under its mechanical strength and also to stop permeation.

Cryogenic target filling and cooling station consists in the following main processes :



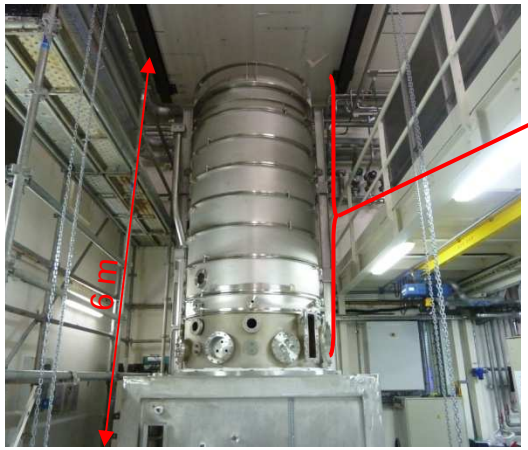
- **DT handling glovebox :** *now under D_2 testing*
- **Back pressure to seal the permeation cell.**
- **Filling cryostat :** *It's composed of a 6 m^3 vacuum chamber where the 6 permeation cells are connected to a cooling system (Stirling machine).*

A cryogenic gripper, held by a 3 axes robot, handles the cryotarget and the cell plugs, which lock the permeation cells, at room or cryogenic temperature.

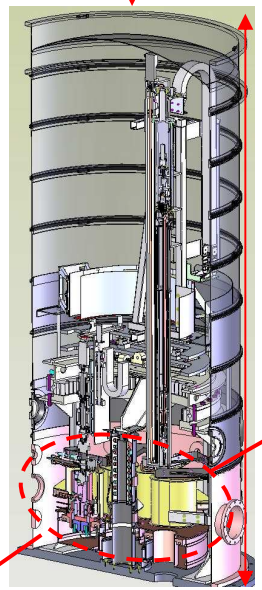


- **Room B54 : Filling cryostat**

The filling cryostat is the heart of 3 gloveboxes.

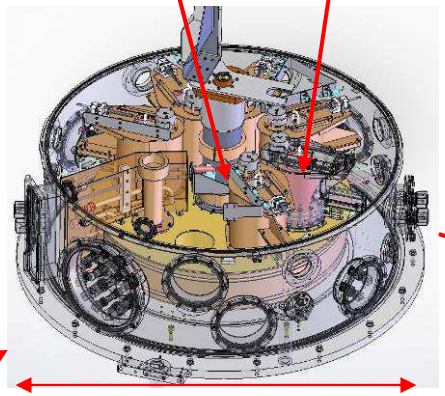


Filling cryostat



Permeation cell thermal shield

Permeation cell

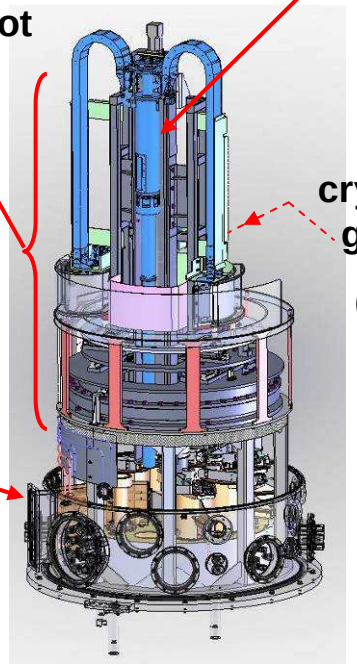


3-axis Robot

Cryogenic gripper

Non cryogenic gripper

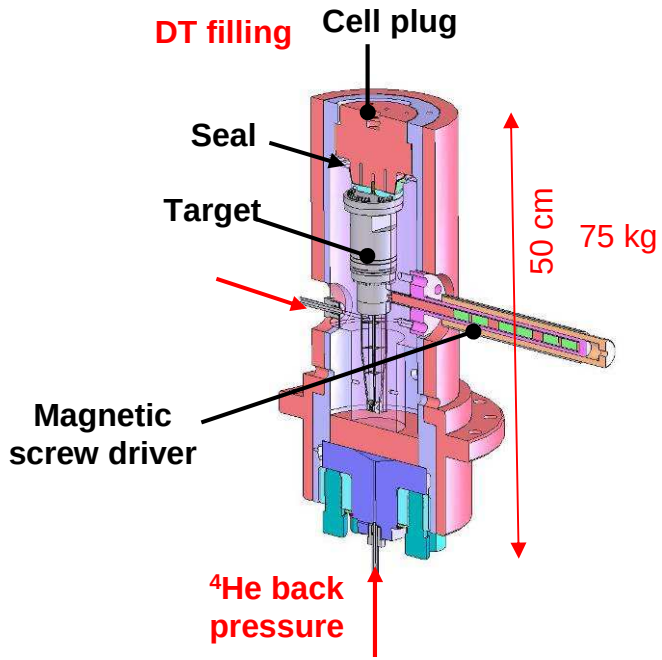
(back)



The filling cryostat holds:

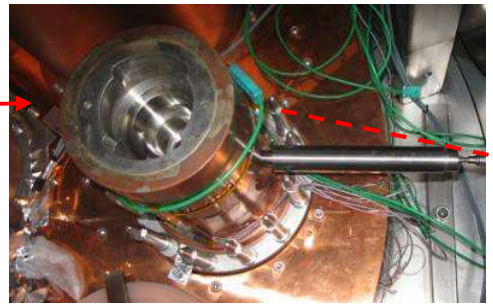
- **6 permeation cells** → filling and cooling of targets (possibly 6 at the same time)
- **A 3-axis robot** → moves and positioning of grippers
- **A cryogenic gripper** → transfer of targets and cell plugs at 300 K and 20 K
- **A non cryogenic gripper** → lock / unlock cell plugs at 300 K and 20 K

- **Filling cryostat : Permeation cell**



Two permeation cells were manufactured and are mounted in the filling cryostat.
Filling cryostat holds 6 permeation cells.

Permeation cell



Permeation cell mounted in the filling cryostat

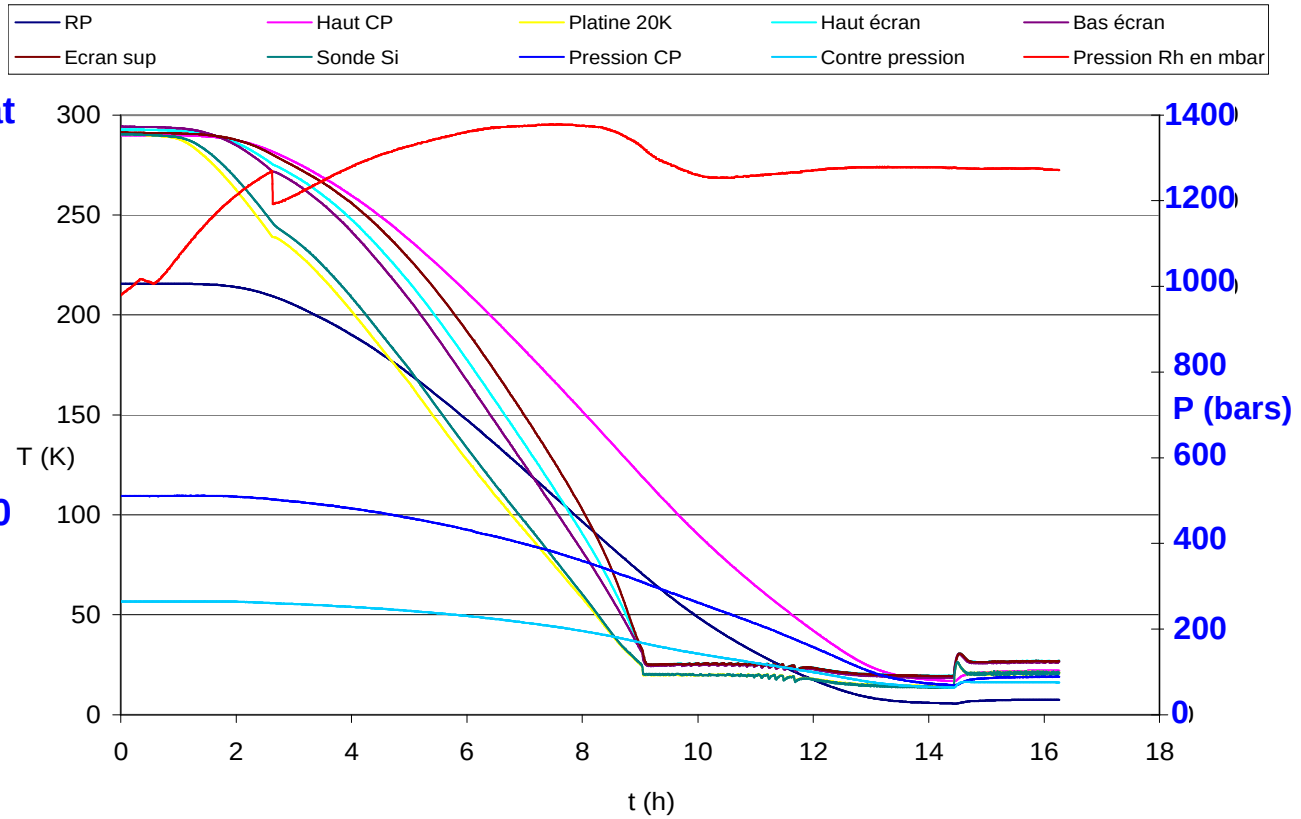
Permeation cell with their individual thermal shields inside filling cryostat

- **Filling cryostat : Permeation cell (long term reliability studies)**

The permeation cell development program led to a final design (3rd generation) that meets all the specifications :

- **Leak level < 10^{-9} mbar.l.s^{-1}** with 1300 bars (copper seal or gilded stainless steel seal)
- **Closing of the holraum gas entry** at 20 K with a **magnetic screw driver**
- **Unlocking of the cell plug at 20 K** with a torque ≤ 2 N.m and possibly application of 2 J shocks on the plug

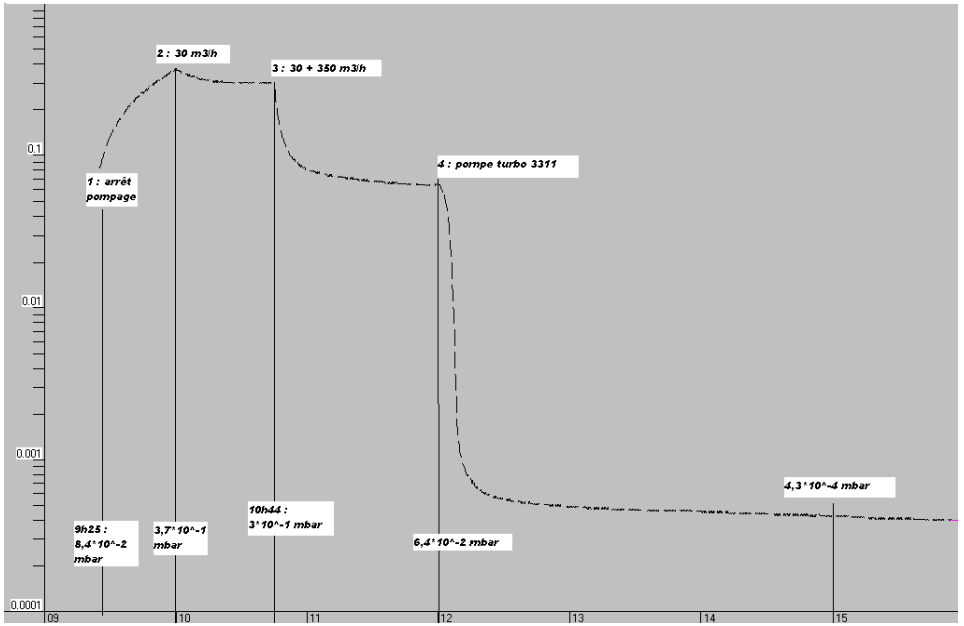
The long term reliability is still under investigation (7 filling and cooling cycles has succeeded).



- **Filling cryostat : Vacuum**

Helium **leak levels of internal gas circuits and vacuum vessels** (including the cryogenic line and filling cryostat ≈ 6m^3) :
< 10^{-9} mbar.l/s

Performances of the filling cryostat pumping system :
2.10^{-5} mbar @ 300 K (2 weeks pumping)
< 10^{-7} mbar @ 20K



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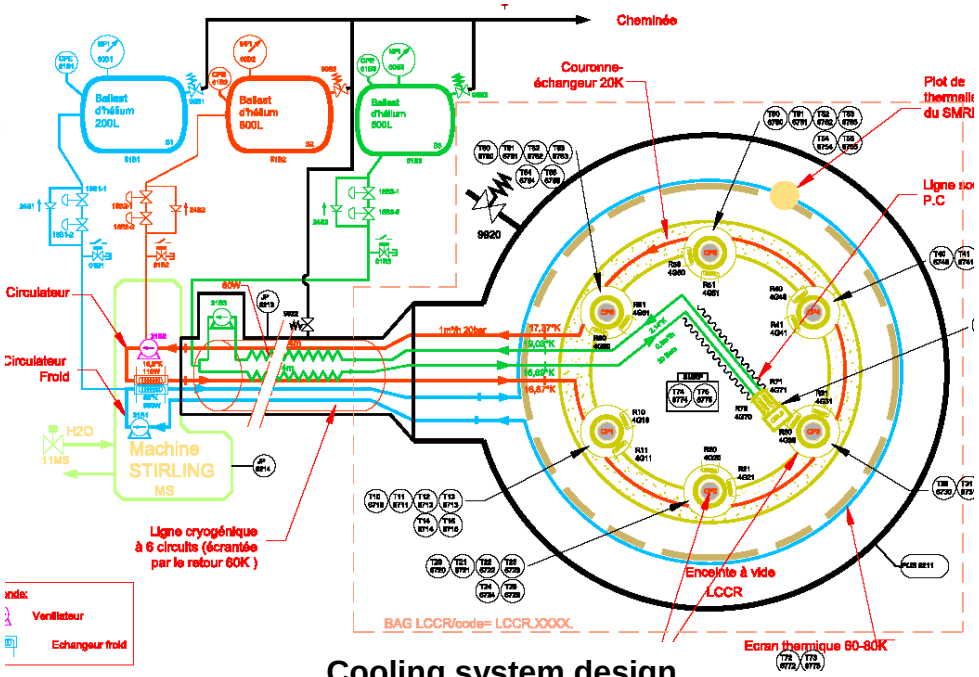
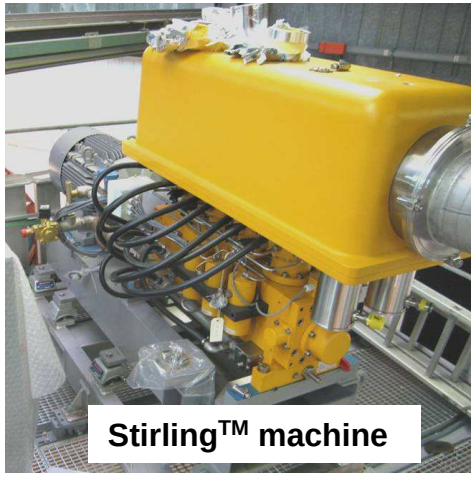
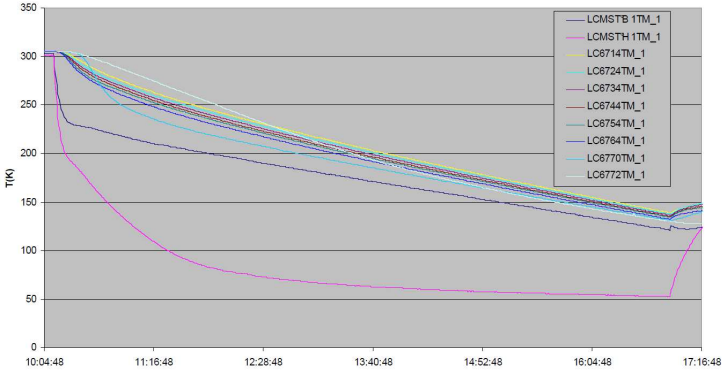
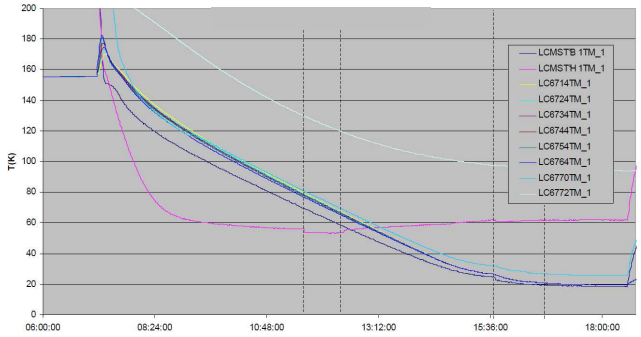
- **Filling cryostat : Cryogeny**



Cooling system design







Filling cryostat cooling system :

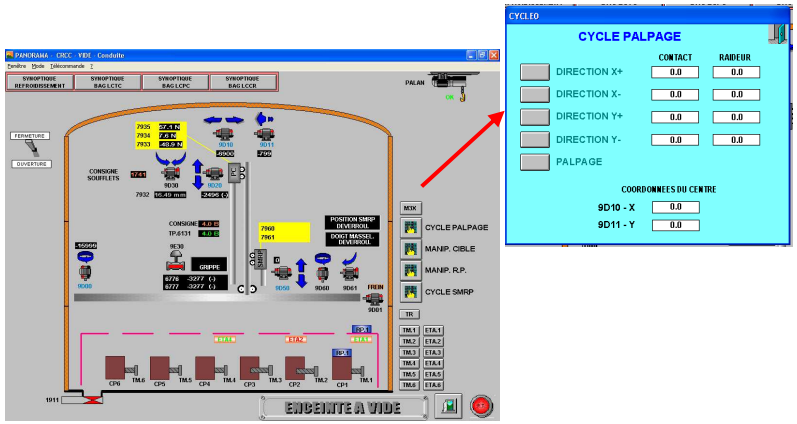
- Stirling™ machine (typical cooling power of 230 W at 20K)
- + triple cryogenic line in closed loop (20 bars of He gas at 20K).

It has now been tested and meets the specifications :

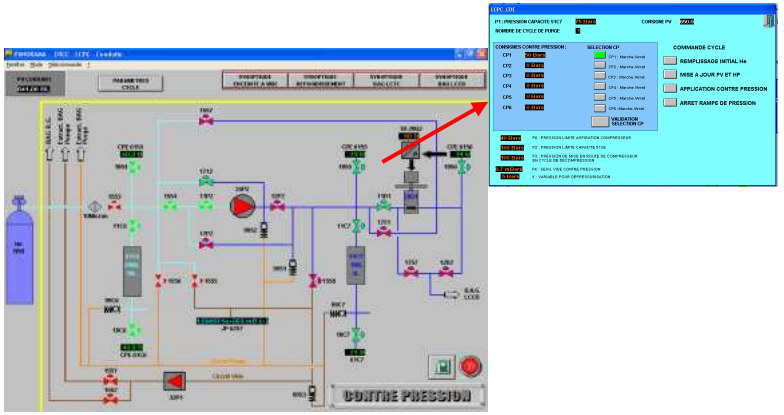
- 600kg of stainless steel and copper coouled in 10 ours
- 20 K at the permeation cell/cooling system interface with 30 W margin
- 21 K at the gripper / target interface
- Above temperatures reached in 18 hours

Filling cryostat : Supervision

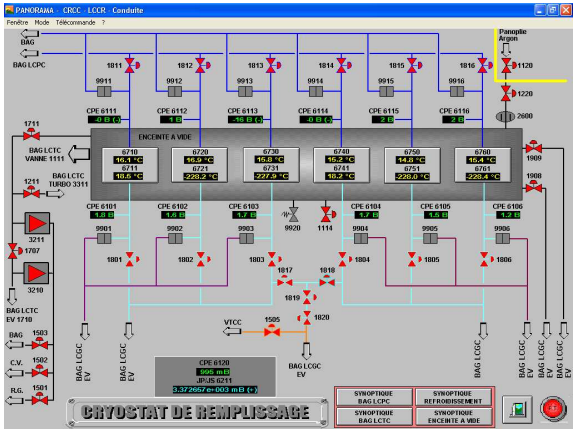
All internal equipments (pumps, valves) and instrumentation of the gloveboxes have been tested and are now **operated and controlled from the supervision terminal included severe nuclear safety procedures**



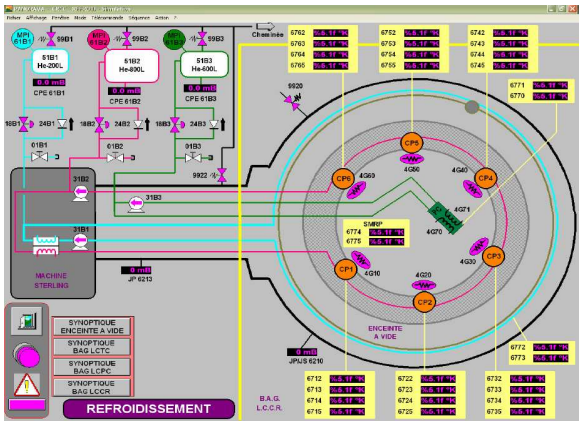
M3X and gripper supervision



Permeation cell pressurization supervision



Cryogenic system supervision



Valves and pumps supervision

- **Filling cryostat : Positioning**

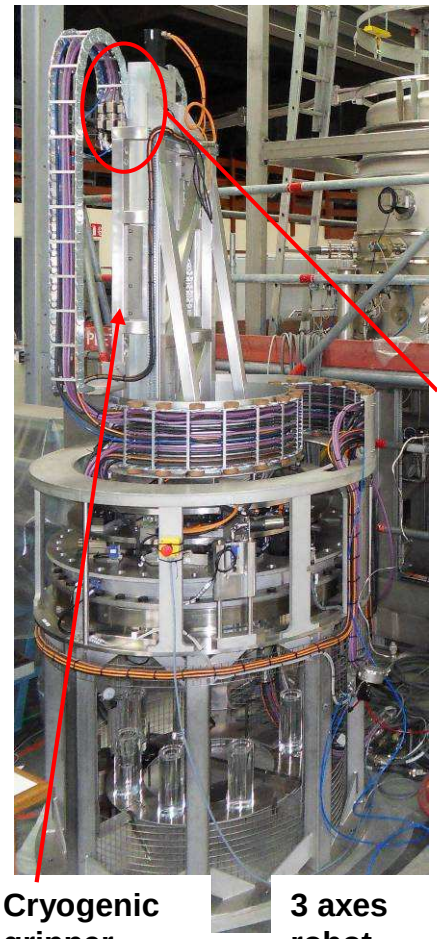
Key point in the testing program : operation of the 3-axis robot and cryogenic gripper

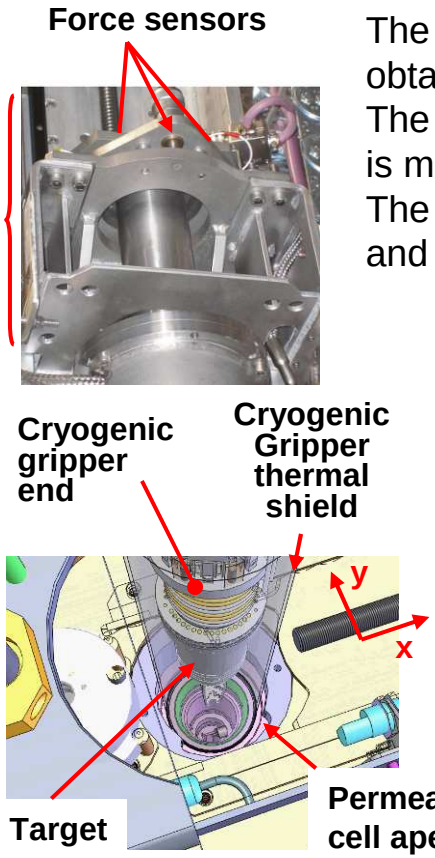
Specifications:

- Precision of 0.1 mm required to transfer permeation cell plugs and targets inside the permeation cell.

- Transfer process fully automated

- Reliability at 300K and 20K despite thermal contractions.





The **positioning precision** of the cryogenic gripper is obtained **through a "palpation" procedure**:
The mechanical connection between the robot and the gripper is made through **3 force sensors mounted at 120°.**
The stiffness of the cryogenic gripper was measured at 300K and 20K.

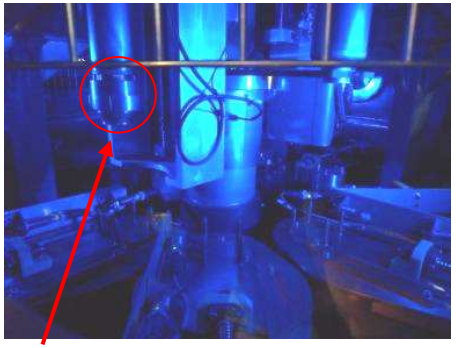
→ Getting the thermal shield of the gripper in contact with the permeation cell's aperture (round shape) at the same level of constraint in the 4 directions (X, Y) allows then to workout the theoretical center of the permeation cell.

- **Filling cryostat : Transfers at room and cryo temp**

Characteristics :

- **Positioning precision of the 3-axis robot : 0.02 mm**
- **Repeatable positioning precision of the palpation procedure : between 0.05 and 0.1 mm for the cryogenic gripper end at 300K**
- **Procedure automated and launched from the supervision terminal**

Target transfer (thermal shield of gripper is removed)



Permeation cell plug transfer

Transport cryostat connected to CRCC

Tested transfers :

- **Transfer of target from vacuum vessel to permeation cell, with the cryogenic gripper at 300K**
- **Transfer of permeation cell plug from vacuum vessel to permeation cell, with the cryogenic gripper at 300K**
- **Locking of permeation cell plug, with the non cryogenic gripper at 300K**
- **Unlocking of permeation cell plug with the non cryogenic gripper at 20K**
- **Transfer of target from permeation cell to transport cryostat, with the cryogenic gripper at 20K**

- **Conclusion**

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The filling cryostat is the heart of a set of gloveboxes for the filling of cryo target by permeation.

The filling cryostat has reached very stretch mechanical and cryogenic objectives.

The installing of gloveboxes at CEA Valduc has started in june 2011 final acceptance is foreseen at mid 2012).

Tests in deuterium will follow implemented all the gloveboxes

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Thank you for your attention